AIRS Level 3: A new radiance based approach for climate compared to V6 Level 3 and ERA-Interim

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Background

AIRS + CrIS Lifetimes Entering Climate Regime

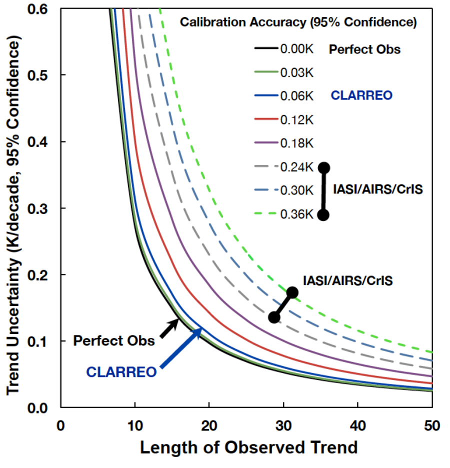
- AIRS products developed for NWP
- Is our existing approach going to meet climate requirements?
- How will we connect AIRS + CrIS + IASI, etc.?

Climate Requirements/Users

- Can Level 2 provide accurate Level 3 climatologies?
- How provide error characterization and traceability?
- Data processing should be as simple as possible so reproducible by others (and is widely understood).
- Open source

AIRS/CrIS/IASI brings a tremendous improvement to climate trending with high vertical sensitivity for T(z), H_2O (z), etc.

Climate Variabililty and Measurement Accuracy



AIRS stability will become more important with time.

AIRS+CrIS: 13+ Years

- Work by S. Leroy shows transition after ~ 12 years
- After which instrument accuracy/stability is dominant error source
- Are the instrument labels correct??
- AIRS stability ~ 0.002K/year?
- AIRS + CrIS SNO difference stats imply “stiching knowledge” to well below 0.01K
- Convert AIRS to CrIS ILS for radiance time series

Alternative Retrieval Path for Climate *Trending*

Two Approaches

1. Derive trends and anomalies in radiance space, then retrieve geophysical variables
2. Examine trends in Probablity Distribution Functions (PDFs) of single channels to focus on extremes).

T(z) and $H_2O(z)$ “Level 3” profile trends and anomalies are key for climate monitoring.

Can we determine L3 errors using this approach?

We just received a NASA Roses award to examine how well AIRS + CrIS can be combined for climate-level trending. (Note: We *need* L1c for this work!)

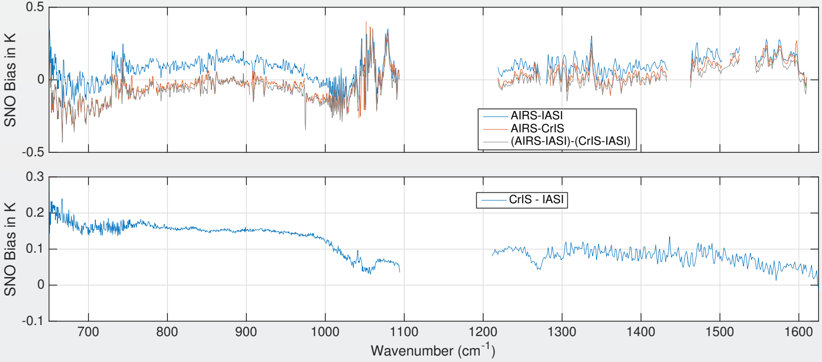
Continuation of AIRS with CrIS: A Proposal

AIRS L1c is a key ingredient

- AIRS only: using L1c means only *one* RTA! That is good!
- L1c makes it easier for others to look at AIRS radiances (public relations mostly, but we need it)
- Convert AIRS to (some TBD) version of CrIS ILS (SNO work below shows we can do this, if we have L1c)
- Convert AIRS to (some version) of CrIS ILS, modify noise
    - Single RTA! Different ILS means different sensitivities and different RTA accuracies.
    - Well understood conversion, not statistical
    - Minimizes effect of ILS on retrievals
    - **Only way to stitch together AIRS and CrIS/IASI and remove radiometric differences from the climate record.**
- This approach makes the processing system simpler in the long run.
- We will be testing this approach in the context of the work shown here using radiance-based trends and anomalies

SNO's Used to Stitch AIRS to CrIS

AIRS SNOs converted to CrIS ILS



- IASI could be used as a "third-party" if CrIS and AIRS are not simultaneously in orbit
- AIRS-IASI SNOs that are only at high latitudes appear very similar to AIRS-CrIS SNOs at all latitudes, on average.

Radiance Based Trending

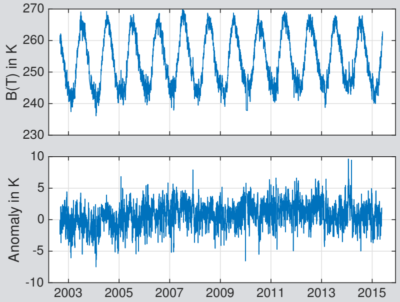
- Operate in radiance space as long as possible (error traceability)
- Lower data volumes (1-2% for some products)
- Data averaging (gridded, zonal)
- Adopt OE retrieval framework with scattering RTA: a-priori for trends is *zero*.
- Using a L1-type Tikhonov empirical smoother with some help from an estimated a-priori covariance.

13-year T(z), H_2O (z) anomalies (zonal) can be processed in 1-2 hours on 40 cpu cores! (Years to test AIRS V6 Level 3!). Linear zonal rates just take a minute to run on 100 layers.

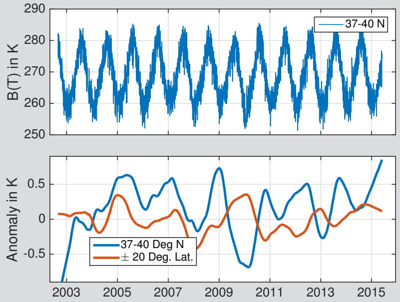
Small data set for use by a larger community

Radiance Time Series and Anomalies

Artic 1231 cm^{-1} Time Series



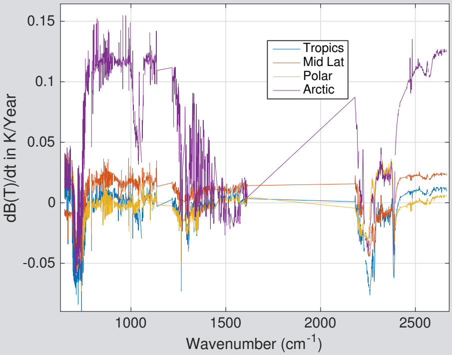
Mid-lat 1231 cm^{-1} Time Series



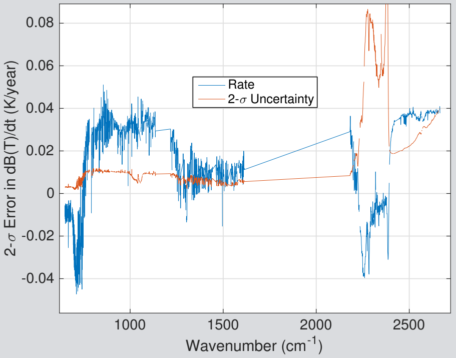
- Data Set: 2378 channels by 40 zonal bins
- Fit to a constant, a time derivative, and annual sinusoids and harmonics.
- Generate jacobians
- Retrieve geophysical rates and anomalies from radiance rates and anomalies.

Radiance Trend Examples

Sample Spectral Rates



45 North Rate with Uncertainty



- Level 2: ~20K Range, 0.2K Noise or S/N ~100
- Trends: ~0.02K Range, 0.002K Noise or S/N ~10
- Very different degrees of freedom, kernel functions

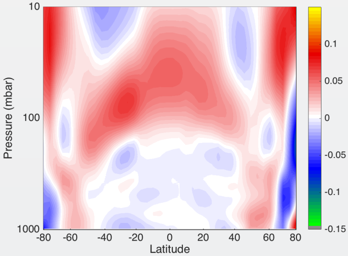
Treatment of Uncertainties in Trends

1. Use simulated data from ERA (one-to-one match with AIRS obs) to estimate OE parameters (L1 smoothing, a-priori covariance)
2. Then compare data sets and *ignore* uncertainty in spectral rates due to inter-annual variability. Trends seem too high for all approaches?
3. Scientifically valid trends: include uncertainty in spectral rates due to geophysical inter-annual variability in UMBC retrieals, trends greatly reduced. But what about AIRS L3 and ERA trends?
4. What are the proper averaging kernels (AK) for profile trends?
5. More simluation work needed to set covariance and L1 smoothing. Minimize kernel ringing.

13-Year Temperature Trends: AIRS (No Obs Errors)

./Figs/Png/obs_temp_smooth.png

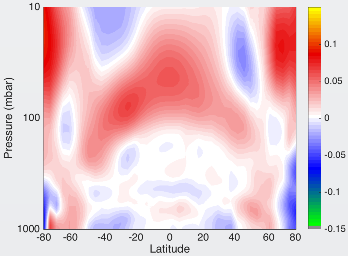
UMBC (K/year).



ERA × Averaging Kernel (K/year)

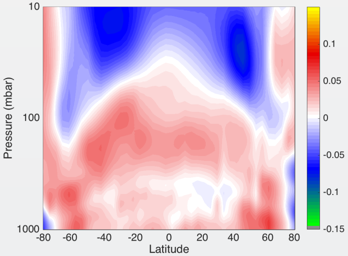
./Figs/Png/13_temp_ak_smooth.png

AIRS Level 3 (K/year)

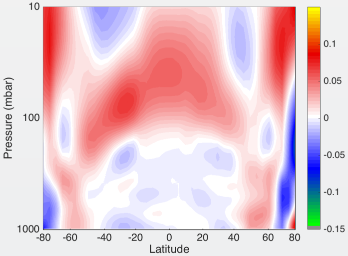


Simulated ERA (K/year)

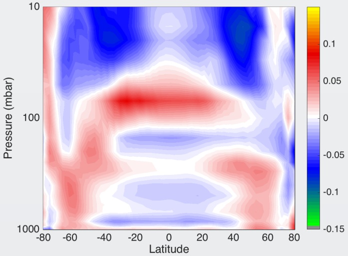
13-Year Temperature Trends: AIRS (No Obs Errors)



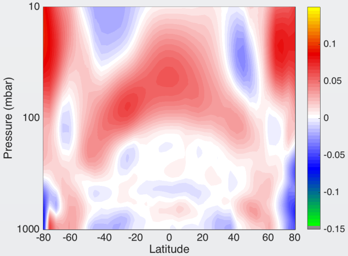
UMBC (K/year).



ERA × Averaging Kernel (K/year)



AIRS Level 3 (K/year)

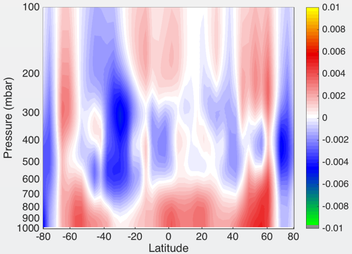


Simulated ERA (K/year)

13-Year Water Vapor Trends (No Obs Errors)

./Figs/Png/obs_water_smooth.png

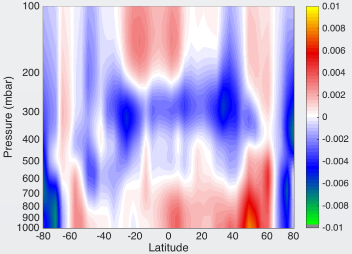
UMBC (fraction/year)



ERA × Averaging Kernel (fraction/year)

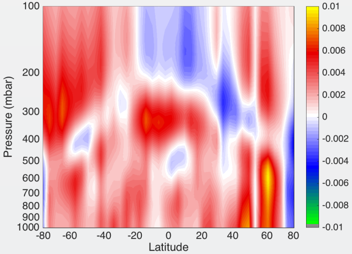
./Figs/Png/13_water_ak_smooth.png

AIRS Level 3 (fraction/year)

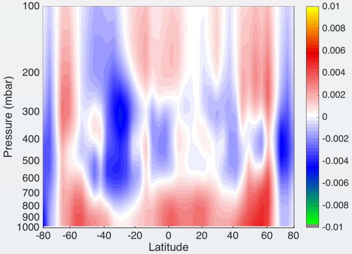


Simulated ERA (fraction/year)

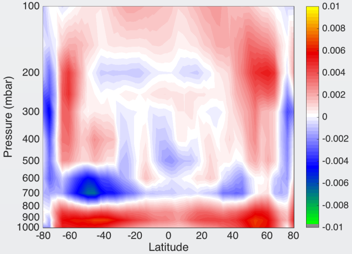
13-Year Water Vapor Trends (No Obs Errors)



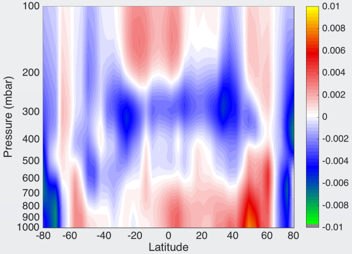
UMBC (fraction/year)



ERA × Averaging Kernel (fraction/year)



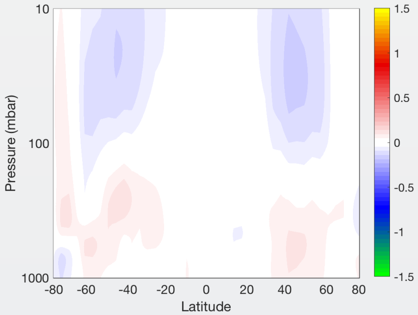
AIRS Level 3 (fraction/year)



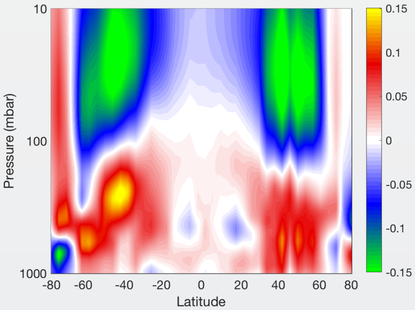
Simulated ERA (fraction/year)

13-Year Linear Temperature Trends

Now including BT rate uncertainties. UMBC uncertainty: 0.03K/Decade



UMBC (K/decade).



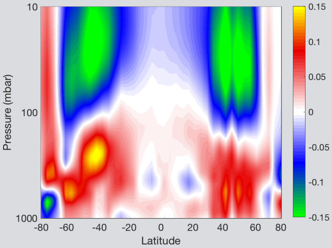
Scale Zoom of UMBC K/decade

Temperature trends lowered by use of linear BT rate uncertainties (inter-annual variability).

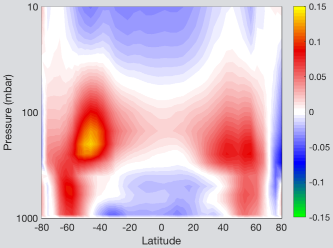
Results sensitive to L1 smoothing, which was set to work well with simulations.

T(z) Trend Comparisons with AIRS L3 and ERA

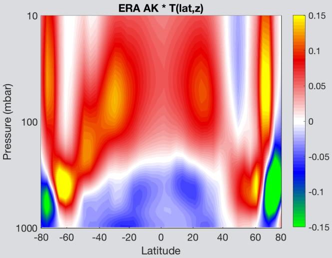
This Work (All trends are K/decade)



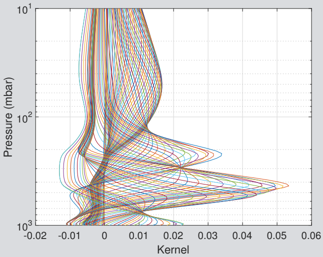
AIRS L3 with AK w/o Rate Errors



ERA with AK using Full Rate Errors

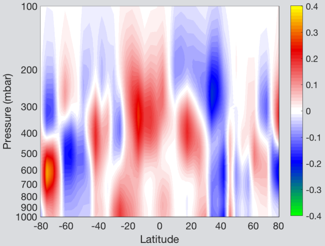


UMBC Averaging Kernels (AK)

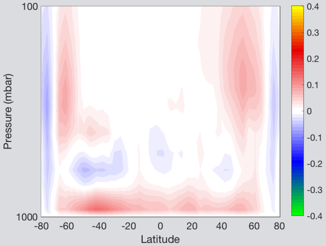


H_2O Comparisons with AIRS L3 and ERA? (%/Year)

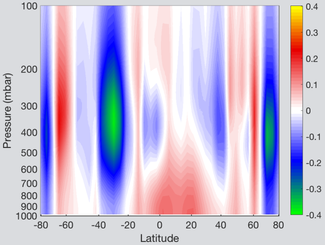
This Work: Unc = ± 0.05%/year



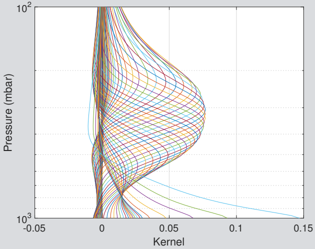
AIRS L3 with AK w/o Rate Errors



ERA with AK using Full Rate Errors

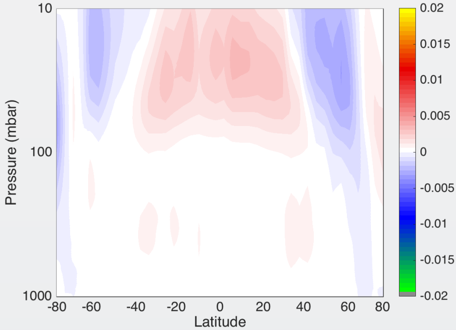


UMBC Averaging Kernels (AK)

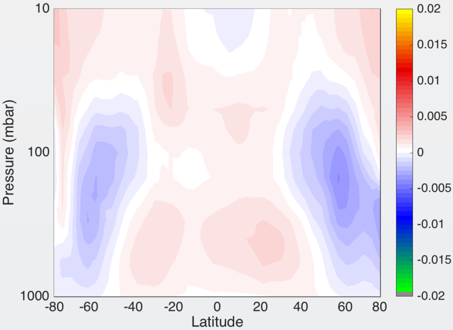


13-Year Ozone Trends?

NO application of AK to AIRS Level 3 Ozone



UMBC (fraction/year).



AIRS Level 3 (fraction/year)

UMBC *Roughly* same rates as Sciamachy for 2000-2010, including latitude dependence in stratosphere.

Zonal T Trend Examples from the Literature

- Zonal trends commonly used in climate/feedback studies
- Zonal averages let's us keep all data in memory
- No reason we cannot transition to gridded trends in the future

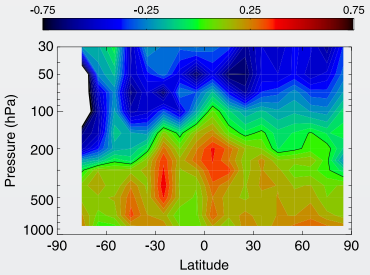
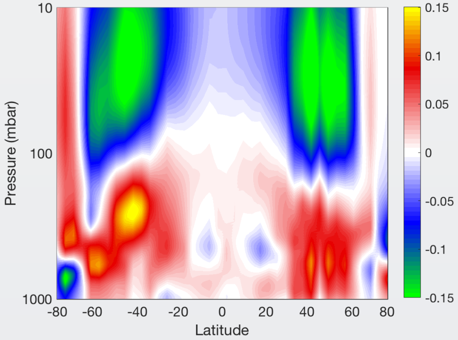
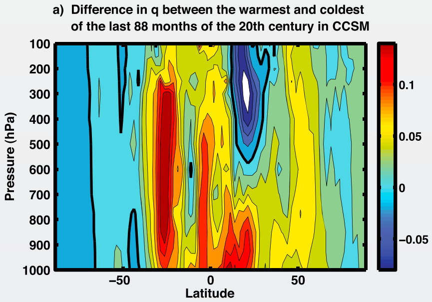
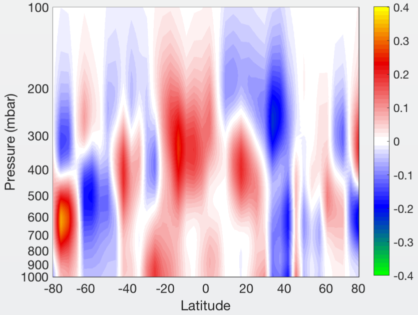


Figure 1. Temperature trend 1960–2012 versus latitude and pressure. The value for each latitude and pressure is the medians of the trends at individual stations in that (10°) latitude bin. Units are °C per decade.



Zonal H_2O Trend Examples from the Literature





Conclusions

Climate trending with AIRS + IASI may need some new approaches.

- Years between AIRS Product versions: 5+
- Overhead of producing all AIRS products is gigantic
- *Very* complex algorithm
- Simpler approaches with smaller datasets may be key in engaging the scientific community with hyperspectral IR for future climate studies.
- We cannot just ignore AIRS and CrIS differences for climate-level research.
- ***Level 3 Algorithm does not estimate errors***
- Trending with AIRS Level 3 might? be problematic.

I believe we should seriously look at using AIRS L1c for standard products and AIRS converted to CrIS for L3-oriented science.